Years of Healthy Life Expectancy, Washington State

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Methods

For the local health indicators project, we computed YHL for 2003–2005 for each local health jurisdiction in Washington. We used BRFSS data and death data for 2003–2005, and the OFM population data that was released in November 2006.

BFRSS data

We combined the individual BRFSS data files for 2003, 2004, and 2005. Each year of BRFSS data is weighted to represent the state (or LHJ) population. In this project, the three combined years should represent the population, so we need to adjust the weights accordingly. We followed Korn and Graubard, chapter 8,[1] and adjusted the weights as follows.

Say n_{2003}, n_{2004}, and n_{2005} are the sample sizes for the 2003, 2004, and 2005 BRFSS samples. Then multiply the weights in the 2003 file by $n_{2003}/(n_{2003} + n_{2004} + n_{2005})$, the weights in the 2004 file by $n_{2004}/(n_{2003} + n_{2004} + n_{2005})$, and the weights in the 2005 file by $n_{2005}/(n_{2003} + n_{2004} + n_{2005})$.

The sample sizes are as follows:

year	sample size
2003	18,644
2004	18,587
2005	23,302

We used the `finalwtw` field in BRFSS for the sampling weight.

STEPS strata

Two additional strata were added to the BRFSS sample design in 2005, and about half of the strata got new codes then. Therefore we recoded the strata before combining them across years.

Life expectancy

First we describe how to calculate life expectancy. The life table for Adams county (Table 1) is displayed as an example. We used the method described by Chiang.[2] The columns P_i and D_i are obtained from state population and death data, respectively. The death rate, M_i is calculated as

$$M_i = D_i/P_i \tag{1}$$

The proportion of the last interval of life lived is calculated by using the death date and birth date to compute the mean number of days lived by people who die during each age interval. This is calculated from the state data, and those numbers are applied in the life table for each local health jurisdiction. Using LHJ data to estimate a_i might lead to imprecise estimates of a_i and increase the variability of the life expectancy estimates. (And that variability would not be reflected in the confidence intervals, since the a_i are assumed to be constants when calculating the variance of the life expectancy.)

The probability of dying during an age interval is defined as proportion of those alive at the beginning of an age group who die during the age interval, and is given by

$$\hat{q}_i = \frac{n \cdot M_i}{1 + n(1 - a_i)M_i} \tag{2}$$

The probability of dying is defined as 1.0 in the 85+ age group.

To construct the life table, one starts with an imaginary cohort of 100,000 people. Then we can calculate the number living at the beginning of each age interval in turn with the relation

$$l_{i+1} = l_i(1 - \hat{q}_i) \tag{3}$$

We can calculate the person-years lived during an age interval with

$$L_i = n_i(l_{i+1} + a_i(l_i - l_{i+1})) \tag{4}$$

For the oldest age interval this is defined as $L_w = l_w/M_w$, where w indicates the oldest age interval.

The total person-years lived by people alive at the beginning of any age interval α is given by the sum of person-years lived during that age interval and all older age intervals:

$$T_\alpha = \sum_{i=\alpha}^{w} L_i \tag{5}$$

where w is the index for the oldest age interval.

The life expectancy for a particular age α is defined as the average person-years lived by people alive at the beginning of that age interval:

$$\hat{e}_\alpha = T_\alpha / l_\alpha \tag{6}$$

For example, the life expectancy at age 0 in Adams county is given by $T_1/L_1 = 7,827,752/100,000 = 78.3$.

Table 1: Life table for Adams county, 2003–2005.

interval	Age range	length of interval	population*	Number of deaths	Deaths per 1,000	Proportion of years lived by those who die in interval†	Probability of dying during interval	Number alive at beginning of interval	Total number of years lived in interval	Number of years lived in this and subsequent intervals	Life expectancy at beginning of interval
i	x_i, x_{i+1}	n_i	P_i	D_i	$1,000 \cdot M_i$	a_i	$\hat{q}_i$	l_i	L_i	T_i	$\hat{e}_i$
1	0	1	927	10	10.79	0.1306	0.0107	100,000	99,071	7,827,752	78.3
2	1-4	4	3,708	2	0.54	0.3756	0.0022	98,931	395,193	7,728,681	78.1
3	5-9	5	4,565	2	0.44	0.4919	0.0022	98,718	493,042	7,333,488	74.3
4	10-14	5	4,462	1	0.22	0.5459	0.0011	98,502	492,260	6,840,447	69.4
5	15-17	3	2,889	3	1.04	0.5832	0.0031	98,392	294,792	6,348,187	64.5
6	18-19	2	1,650	1	0.61	0.5120	0.0012	98,086	196,055	6,053,395	61.7
7	20-24	5	3,533	4	1.13	0.4992	0.0056	97,967	488,449	5,857,339	59.8
8	25-29	5	3,144	7	2.23	0.4705	0.0111	97,414	484,215	5,368,890	55.1
9	30-34	5	3,160	5	1.58	0.5460	0.0079	96,336	479,954	4,884,676	50.7
10	35-39	5	2,978	6	2.01	0.5405	0.0100	95,576	475,679	4,404,721	46.1
11	40-44	5	3,119	8	2.56	0.5327	0.0127	94,618	470,271	3,929,042	41.5
12	45-49	5	3,321	5	1.51	0.5275	0.0075	93,412	465,403	3,458,771	37.0
13	50-54	5	2,838	12	4.23	0.5220	0.0209	92,711	458,918	2,993,368	32.3
14	55-59	5	2,636	15	5.69	0.5040	0.0281	90,771	447,538	2,534,449	27.9
15	60-64	5	2,083	15	7.20	0.5026	0.0354	88,224	433,361	2,086,911	23.7
16	65-69	5	1,559	27	17.32	0.5143	0.0831	85,104	408,343	1,653,550	19.4
17	70-74	5	1,304	22	16.87	0.5296	0.0811	78,030	375,259	1,245,207	16.0
18	75-79	5	994	51	51.31	0.5263	0.2288	71,699	319,644	869,948	12.1
19	80-84	5	738	51	69.07	0.5136	0.2957	55,297	236,723	550,303	10.0
20	85+	.	692	86	124.20	.	1.0000	38,947	313,580	313,580	8.1

* the population figures are the sum across all three years.
† a_i is calculated from state data.

Years of healthy life expectancy

Years of Healthy Life expectancy (YHL) is defined as the average number of healthy years lived.[3] It is easily calculated from the life table. If $\hat{h}_i$ is the proportion of people who report good health in age interval i, then the number of person-years lived in a healthy state in that age interval is given by

$$L'_i = \hat{h}_i \cdot L_i \tag{7}$$

and the average number of years lived in a healthy state by people alive at the beginning of age interval α is given by

$$\hat{e}'_\alpha = \frac{1}{l_\alpha} \sum_{i=\alpha}^{w} L'_i \tag{8}$$

Variance of the life expectancy

We used the formula for the variance of the life expectancy that was derived by Chiang:[2]

$$\text{Var}(\hat{e}_\alpha) = \sum_{i=\alpha}^{w-1} \hat{p}_{\alpha i}^2 [(1-a_i)n_i + \hat{e}_{i+1}]^2 s_{\hat{p}_i}^2 \tag{9}$$

where

$$\hat{p}_{\alpha i} = l_i / l_\alpha$$

and

$$s_{\hat{p}_i}^2 = \frac{\hat{q}_i^2(1-\hat{q}_i)}{D_i}$$

Note that in this formulation, the oldest age interval is assumed to make no contribution to the variance.

Variance of YHL

Ignoring the variability in death rates

If the number of deaths is much larger than the number of survey respondents, one can safely ignore the variability in death rates when calculating the variance of YHL. In that case, the variance of YHL is calculated as follows.

$$\begin{aligned} \text{Var}(\hat{e}'_\alpha) &= \text{Var}\left(\frac{1}{l_\alpha}\sum_{i=\alpha}^{w} L'_i\right) \qquad (10) \\ &= \left(\frac{1}{l_\alpha}\right)^2 \sum_{i=\alpha}^{w} \text{Var}(L'_i) \end{aligned}$$

$$= \left(\frac{1}{l_\alpha}\right)^2 \sum_{i=\alpha}^{w} L_i^2 \text{Var}(\hat{h}_i)$$

where $\text{Var}(\hat{h}_i)$ is obtained by analysing the survey data (e.g. with SUDAAN or STATA). This formula is valid under the assumption that health status is independent across age groups.

Accounting for variability in death rates

If the number of deaths is about the same as, or fewer than, the number of survey respondents, then ignoring the variability in the death rates may lead to an underestimation of the variance of YHL. Here we describe the derivation of a formula for the variance of YHL that accounts for the variability in death rates.

First, note that

$$\hat{e}_\alpha = \sum_{i=\alpha}^{w} L_i / l_\alpha \tag{11}$$

and from Equation 9,

$$\text{Var}\left(\sum_{i=\alpha}^{w} L_i / l_\alpha\right) = \sum_{i=\alpha}^{w-1} \hat{p}_{\alpha i}^2 [(1-a_i)n_i + \hat{e}_{i+1}]^2 s_{\hat{p}_i}^2 \tag{12}$$

This implies that

$$\text{Var}(L_i/l_\alpha) = \begin{cases} \hat{p}_{\alpha i}^2 [(1-a_i)n_i + \hat{e}_{i+1}]^2 s_{\hat{p}_i}^2 & \text{for } i = 1, \ldots, w-1 \\ 0 & \text{for } i = w \end{cases} \tag{13}$$

and

$$\text{Var}(L_i) = \begin{cases} l_i^2 [(1-a_i)n_i + \hat{e}_{i+1}]^2 s_{\hat{p}_i}^2 & \text{for } i = 1, \ldots, w-1 \\ 0 & \text{for } i = w \end{cases} \tag{14}$$

since $\hat{p}_{\alpha i} = l_i / l_\alpha$.

Now we use the identity $\text{Var}(XY) = X^2\text{Var}(Y) + Y^2\text{Var}(X) + \text{Var}(X)\text{Var}(Y)$ (if X and Y are independent) to get

$$\text{Var}(\hat{h}_i \cdot L_i) = \hat{h}_i^2 \text{Var}(L_i) + L_i^2 \text{Var}(\hat{h}_i) + \text{Var}(\hat{h}_i)\text{Var}(L_i) \tag{15}$$

and finally,

$$\text{Var}(\hat{e}'_\alpha) = \left(\frac{1}{l_\alpha}\right)^2 \sum_{i=\alpha}^{w} \left(\hat{h}_i^2 \text{Var}(L_i) + L_i^2 \text{Var}(\hat{h}_i) + \text{Var}(\hat{h}_i)\text{Var}(L_i)\right) \tag{16}$$

References

1. Korn EL, Graubard BI. Analysis of health surveys. New York: John Wiley & Sons, 1999.
2. Chiang CL. Life table and mortality analysis. Geneva: World Health Organization, 1977.
3. Molla MT, Wagener DK, Madans JH. Summary measures of population health: methods for calculating healthy life expectancy. Healthy People 2010 Stat Notes 2001; 1–11.